CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Kitchen Ventilation

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team September 2011

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1. Introduction

Through Codes and Standards Enhancement (CASE) Studies, the California Investor Owned Utilities (IOUs) provide standards and code-setting bodies with the technical and cost-effectiveness information required to make informed judgments on proposed regulations for promising energy efficiency design practices and technologies.

The IOUs began evaluating potential code change proposals in fall 2009. Throughout 2010 and 2011, the IOU CASE Team (Team) evaluated costs and savings associated with each code change proposal. The Team engaged industry stakeholders to solicit feedback on the code change proposals, energy savings analyses, and cost estimates. This CASE Report presents the IOU code change proposal for kitchen ventilation. The contents of this report, including cost and savings analyses and proposed code language, were developed taking feedback from the solar and building industries and the California Energy Commission (CEC) into account.

All of the main approaches, assumptions and methods of analysis used in this proposal have been presented for review at three public Stakeholder Meetings hosted by the IOUs. At each meeting, the CASE team asked for feedback on the proposed language and analysis thus far, and sent out a summary of what was discussed at the meeting, along with a summary of outstanding questions and issues.

A record of the Stakeholder Meeting presentations, summaries and other supporting documents can be found at www.calcodesgroup.com. Stakeholder meetings were held on the following dates and locations:

- First Stakeholder Meeting: May , 2010, San Ramon Conference Center, San Ramon, CA
- Second Stakeholder Meeting: November 10, 2010, Webinar
- Working Session: January 20, 2010, Webinar
- Third Stakeholder Meeting: April 5, 2011, Webinar

Specific stakeholder comments addressed in Section 5 of this report.

2. Overview

2.1 Measure Title

Kitchen Ventilation

2.2 Description

The following describes four energy saving measures associated with commercial kitchen ventilation. Mechanical systems serving commercial kitchens are not currently regulated by Title 24. The origin of these proposed measures is found in recent amendments to ASHRAE 90.1 titled 90.1ax. Some details of these proposed measures deviate slightly from the measures found in 90.1ax.

The four propose measures shall address:

1. Direct Replacement of Exhaust Air Limitations
2. Type I Exhaust Hood Airflow Limitations
3. Makeup and Transfer Air Requirements
4. Commercial Kitchen System Efficiency Options

2.2.1 Measure 1: Direct Replacement of Exhaust Air Limitation

Commercial kitchen systems dedicated to exhausting air and providing makeup are not currently regulated in the Title 24 Energy Code. The proposed measure is intended to be included as a new code section dedicated to reducing the energy impact of these systems.

Kitchen grease hoods require replacement air to be introduced to the room in which they are located. Commonly, this replacement air is distributed outside of the hood within the room. As kitchens are occupied spaces, this replacement air may require heating or cooling to maintain a comfortable work environment. There is a type of hood where a portion of the replacement air is injected directly into the hood which is intended to provide the necessary makeup for the exhaust air but also, because the air never leaves the hood, reduces the need to condition the replacement air. These hoods are generally called "short-circuit" hoods. This was the promise of short-circuit hoods: that you could provide the same amount of exhaust air as an exhaust-only hood but reduce energy costs by not having to condition the makeup air. The reality of short-circuit hoods, however, is quite different.

Research by the American Gas Association and California Energy Commission has shown that direct supply of makeup air, in excess of 10% of hood exhaust airflow, into the hood cavity significantly deteriorates the Capture and Containment (C&C) performance of hoods (PIER, 2002). This research has also demonstrated that short-circuit hoods waste energy and/or degrade kitchen environment and hygiene compared to exhaust-only hoods. If we assume a generic baseline C&C rate for a cooking process, the study shows the exhaust rates for short-circuit hoods generally exceed those for exhaust-only hoods by at least the amount of air short-circuited, thus decreasing performance and increasing energy consumption. Therefore, this measure essentially outlaws "short-circuit" hoods.

The proposed measure is to add the following language:

"Replacement air introduced directly into the hood cavity of kitchen exhaust hoods shall not exceed 10% of the hood exhaust airflow rate."

2.2.2 Measure 2: Type I Exhaust Hood Airflow Limitations

This measure is intended to eliminate the wasteful common practice of specifying excessive exhaust airflow by selecting hoods that are not UL listed or have not been subjected to a recognized performance test. The current California Mechanical Code Section 508.4 requires non-listed Type 1 hoods to have a minimum exhaust airflow rate that is determined by the hood size, hood configuration and cooking appliance duty. Non-listed hoods may be factory or field-built. Listed hoods are labeled factory-built exhaust hoods in accordance with UL 710 and generally have airflow rates lower than the code minimums for non-listed hoods. ASHRAE publishes a standard, Standard 154, which addresses general kitchen exhaust issues and also establishes airflow minimums for all Type I hoods separated into cooking duty and hood style classifications. The airflow minimums in the CMC and in ASHRAE Standard 154 are similar by cooking duty and hood style.

In 2006, ASHRAE published the results of Research Project 1202 which showed that hoods listed per UL Standard 710 and/or engineered and tested per ASTM/ANSI 1704 have exhaust rates that are at least 30% less than the Std 154 exhaust airflow minimums. Table 1 includes the resultant 30% better values. The proposed measure would require all Type 1 hoods in large kitchens to have airflow rates that are no higher than the rates established by this study. The general effect is that only listed hoods will comply with this measure. Unlisted hoods shall still be required to meet the minimums established in the mechanical code and thereby do not satisfy this energy code requirement. The intent is to conserve energy through the use of engineered hoods or performance based hoods that have been validated based on consensus standard test methods.

This measure should not increase first cost and in many cases will reduce first cost through downsizing of exhaust, supply and cooling/heating equipment.

A 5,000 CFM threshold is maintained to exempt small restaurants but include larger restaurants and commercial/institutional kitchens. The statement "a facility has a total Type I and Type II kitchen hood exhaust airflow rate greater than 5,000 cfm" is included to prevent the use of multiple hoods or hood sections in an effort to keep individual hood exhaust beneath 5,000 cfm thus avoiding the energy saving methods required in the proposed Energy Efficiency measure.

An exception is provided for kitchen designs that replace at least 75% of exhausted air with transfer air.

2.2.3 Measure 3: Makeup and Transfer Air Requirements

Commercial kitchen systems dedicated to exhausting air and providing makeup are not currently regulated in the Title 24 Energy Code. This proposed code measure is intended to reduce the energy impact of these systems.

Engineers are often in the habit of simply providing 100% outside air makeup air units in kitchens to provide makeup air equal to the exhaust flow rate even when "free" transfer air is available from adjacent or nearby spaces. Adding makeup air when transfer air is available is a wasteful design practice and should be discouraged. Using available transfer air saves energy and reduces the first cost of the makeup unit and exhaust system in the adjacent spaces. It simply requires some engineering and coordination to provide a path for the transfer air.

The proposed measure is:

Mechanically cooled or heated makeup air delivered to any space with a kitchen hood shall not exceed the greater of:

a) The supply flow required to meet the space heating and cooling load
b) The hood exhaust flow minus the available transfer air from adjacent spaces.

Available transfer air is that portion of outdoor ventilation air serving adjacent spaces not required to satisfy other exhaust needs (such as restrooms), not required to maintain pressurization of adjacent spaces, and that would otherwise be relieved from the building.

2.2.4 Measure 4: Commercial Kitchen System Efficiency Options

This proposed measure seeks to impose limitations on the commercial kitchen makeup air. Designers of large kitchen exhaust shall choose between four options intended to save energy to deliver and condition makeup air depending on specific project criteria. The proposed code statement is:

Make-up Airflow Limitations. A kitchen/dining facility having a total Type I and Type II kitchen hood exhaust airflow rate greater than 5,000 cfm shall have at least one of the following:

a) At least 50% of all replacement air is transfer air that would otherwise be exhausted.
b) Demand ventilation system(s) on at least 75% of the exhaust air. Such systems shall:
    1) Include controls necessary to modulate airflow in response to appliance operation and to maintain full capture and containment of smoke, effluent and combustion products during cooking and idle
    2) Include failsafe controls that result in full flow upon cooking sensor failure
    3) Allow occupants the ability to temporarily override the system to full flow
    4) Be capable of reducing exhaust and replacement air system airflow rates to the larger of:
        i. 50% of the total design exhaust and replacement air system airflow rates
        ii. The ventilation rate required per Section 121
c) Listed energy recovery devices with a sensible heat recovery effectiveness of not less than 40% on at least 50% of the total exhaust airflow.
d) A minimum of 75% of makeup air volume is:
    a. Heated to no more than 60°F
    b. Cooled without the use of mechanical cooling

The energy opportunity that is analyzed within this measure is demand control ventilation (DCV) for kitchen hoods. Common kitchen exhaust systems typically only have ON/OFF control for kitchen and makeup fan systems. DCV systems, in contrast, react to the smoke and heat from cooking surfaces and modulate the hood exhaust airflow rates accordingly. These systems also have the ability to modulate the makeup air systems airflow rates. The energy savings is produced from the reduced power consumption of the exhaust and makeup air fans and reduced energy to condition makeup air.

2.3 Type of Change

The proposed additions to the code are Prescriptive Measures applying to commercial kitchen systems.

2.4 Energy Benefits

2.4.1 Measure 1: Direct Replacement of Exhaust Air Limitation

Short-circuit hoods require higher air flow rates to equal the capture and containment performance of an exhaust-only hood. A typical direct replacement (short-circuit) hood injects 50%-80% of the exhaust air volume into the hood. Exhaust air rates for short-circuit hoods are approximately 50% more than equally performing exhaust-only hoods. The replacement air rates are thereby also greater for short-circuit hood systems.

The energy required to move larger air volumes in both the exhaust and the makeup systems is inherently greater for short-circuit hood systems.

2.4.2 Measure 2: Type I Exhaust Hood Airflow Limitations

Energy is saved as kitchen exhaust air volumes are reduced. Savings manifest from reduced exhaust fan energy and the corresponding reduced makeup system fan and conditioning energy.

	Electricity Savings (kwh/yr)	**Demand Savings (W)**	**Natural Gas Savings (Therms/yr)**	**TDV Electricity Savings**	**TDV Gas Savings**
Per design cfm	2.71	0.502	0	-	0
Savings per square foot	4.21	0.779	0	-	0

2.4.3 Measure 3: Makeup and Transfer Air Requirements

The energy required to deliver and mechanically condition outside air as replacement air is generally greater than the energy to use transfer air. Transfer air is a valuable low energy resource that needs to be fully exploited. By maximizing the use of transfer air, significant amounts of energy can be saved.

	Electricity Savings (kwh/yr)	**Demand Savings (W)**	**Natural Gas Savings (Therms/yr)**	**TDV Electricity Savings**	**TDV Gas Savings**
Savings per square foot	8.02	1.37	0.08	-	-

2.4.4 Measure 4: Commercial Kitchen System Efficiency Options

Energy is saved as kitchen exhaust air volumes are reduced. Savings manifest from reduced exhaust fan energy and the corresponding reduced makeup system fan and conditioning energy.

	Electricity Savings (kwh/yr)	**Demand Savings (W)**	**Natural Gas Savings (Therms/yr)**	**TDV Electricity Savings**	**TDV Gas Savings**
Savings per square foot	31.11	5.36	0.32	-	-

2.4.5 Statewide Energy Savings for all Measures

The savings from this/these measures results in the following statewide first year savings:

Measure	Statewide Power Savings (MW)	Statewide Electricity Savings (GWh)	Statewide Natural Gas Savings (million Therms)	Total TDV Savings ($)*
Measure 1: Direct Replacement of Exhaust Air Limitation	No significant energy savings			
Measure 2: Type I Exhaust Hood Airflow Limitations	1.803	9.74	0	-
Measure 3: Makeup and Transfer Air Requirements	3.177	18.55	0.192	-
Measure 4: Commercial Kitchen System Efficiency Options	12.414	72.00	0.742	-
TOTAL	**17.394**	**100.28**	**0.934**	-

* TDV savings represent the cost savings that accrue over the entire measure life.

2.5 Non-Energy Benefits

2.5.1 Measure 1: Direct Replacement of Exhaust Air Limitation

The non-energy benefit to this measure is the preservation of a suitable kitchen workplace environment from adequate grease hood capture and containment.

2.5.2 Measure 2: Type I Exhaust Hood Airflow Limitations

Listed hoods have similar costs to unlisted hoods. Equipment and duct savings result from the reduction in airflow by reducing the size for exhaust fans, makeup air fans, and heating and cooling equipment.

2.5.3 Measure 3: Makeup and Transfer Air Requirements

Non-energy benefits include reduced consumption of raw materials since fewer and small makeup air units will be manufactured. There could also be acoustical benefits from reducing the size of the makeup air unit and the exhaust system in the adjacent spaces.

2.5.4 Measure 4: Commercial Kitchen System Efficiency Options

Demand control ventilation systems provide numerous non-energy benefits including reduced noise, improved comfort, and reduced risk of setting off the fire alarm and fire suppression systems. With constant volume hoods, the cooks often try to keep the hoods off as much as possible due to the noise and cold drafts created by the hoods but at the risk of not maintaining adequate ventilation. Hoods equipped with DCV control energize and ramp up exhaust and makeup systems automatically based on cooking duty to minimize noise while maintaining ventilation requirements and occupant comfort.

2.6 Environmental Impact

There are no direct environmental impacts of these measures. These measures will save energy over time relative to current unregulated kitchen system designs which in turn will reduce the use of energy resources and emissions of global warming gases.

2.7 Technology Measures

2.7.1 Measure Availability:

Measure 1: Direct Replacement of Exhaust Air Limitation

Short-circuit hoods represent approximately 1% of the California kitchen hood market. This measure supports the already predominate use of exhaust-only type hoods.

Measure 2: Type I Exhaust Hood Airflow Limitations

Listed hoods are more common than unlisted hoods in the current market. There are no practical or economic barriers associated with compliance with this measure.

Measure 3: Makeup and Transfer Air Requirements

Transfer air is available to most kitchen facilities in some amount. This measure is intended to use available air to minimize energy use and energy costs. No new equipment, controls, or strategies are required to satisfy this measure.

Measure 4: Commercial Kitchen System Efficiency Options

Demand Control Ventilation systems have become increasingly available from several different vendors including Melink, CaptureAire, and Halton. Though the technology is not fully adopted by the design community, there are ample resources available for designers and installers to become educated and implement DCV systems economically.

2.7.2 Useful Life, Persistence, and Maintenance:

Energy savings from these measures will persist for the life of the systems.

2.8 Performance Verification of the Proposed Measure

2.8.1 Measure 1: Direct Replacement of Exhaust Air Limitation

Compliance with this measure shall be enforced during plan check review by the authority having jurisdiction.

2.8.2 Measure 2: Type I Exhaust Hood Airflow Limitations

There is no performance verification requirement for this measure.

2.8.3 Measure 3: Makeup and Transfer Air Requirements

Compliance with this measure shall be enforced during plan check review by the authority having jurisdiction. The code officials shall review the exhaust and makeup air systems for use of transfer air and require clarification if no transfer air is used as replacement air.

2.8.4 Measure 4: Commercial Kitchen System Efficiency Options

Compliance with the DCV component of this measure will be recorded on a new acceptance test form that will require the responsible party to demonstrate that all Type I hoods provide adequate capture and containment whether they are constant volume or DCV style.

2.9 Cost Effectiveness

2.9.1 Measure 1: Direct Replacement of Exhaust Air Limitation

This measure is cost effective because exhaust-only hoods have lower first cost and lower energy cost compared to short-circuit hoods. The cost of the short-circuit hood is approximately 70% greater than an equivalently performing exhaust-only hood. Exhaust fans, makeup air fans, makeup conditioning systems, duct sizes, duct fire protection systems and electrical systems are larger and have higher costs than equivalent equipment for exhaust-only hood systems.

2.9.2 Measure 2: Type I Exhaust Hood Airflow Limitations

This measure is cost effective because listed hoods have cost parity with unlisted hoods but the exhaust fans, makeup air fans, makeup conditioning systems, duct sizes, duct fire protection systems and electrical systems are larger and have higher costs than equivalent equipment for systems using listed hoods complying with this measure.

2.9.3 Measure 3: Makeup and Transfer Air Requirements

This measure is cost-effective because it does not require any additional system costs and it has been shown to save energy. Replacement air system that fully exploits the energy savings from available transfer air consistently use less energy than equivalent systems that condition 100% of replacement air.

2.9.4 Measure 4: Commercial Kitchen System Efficiency Options

For this measure to be cost effective it is not necessary to show that all 4 options are cost effective. It is only necessary to show that at least one option is cost effective in the vast majority of the kitchens where this measure would be required. The transfer air and unconditioned makeup air options are always cost effective (compared to fully conditioned 100% outside air makeup) but these options are not always available (insufficient available transfer air) or desirable (unconditioned makeup air). Therefore, the supporting analysis demonstrates that Demand Control Ventilation systems are cost effective for kitchens that do not meet or want the transfer air or unconditioned makeup air options. More discussion of cost-effectiveness is provided in the Analysis and Results section.

2.9.5 Current Measure Costs

Measure 1: Direct Replacement of Exhaust Air Limitation

There are no costs to adopting this measure.

Measure 2: Type I Exhaust Hood Airflow Limitations

There are no incremental first costs to adopting this measure.

Measure 3: Makeup and Transfer Air Requirements

There are no costs to adopting this measure.

Measure 4: Commercial Kitchen System Efficiency Options

See the Analysis and Results section for a discussion on the current measure costs.

2.9.6 Post Adoption Measure Costs

Measure 1: Direct Replacement of Exhaust Air Limitation

There are no costs to adopting this measure.

Measure 2: Type I Exhaust Hood Airflow Limitations

There are no incremental costs to adopting this measure.

Measure 3: Makeup and Transfer Air Requirements

There are no costs to adopting this measure.

Measure 4: Commercial Kitchen System Efficiency Options

There are no incremental post adoption measure costs aside from incremental maintenance.

2.9.7 Maintenance Costs

Measure 1: Direct Replacement of Exhaust Air Limitation

There are no costs to adopting this measure.

Measure 2: Type I Exhaust Hood Airflow Limitations

There is no incremental maintenance cost increase associated with this measure.

Measure 3: Makeup and Transfer Air Requirements

There is no maintenance cost increase associated with this measure.

Measure 4: Commercial Kitchen System Efficiency Options

There are no or minimal incremental maintenance costs associated with the transfer air or unconditioned makeup air design options.

DCV maintenance costs are incrementally higher than an exhaust system without it. The additional costs relate to maintenance of the sensors, variable speed drives and controllers. These costs are not well known at this time given the relative newness of these types of systems. The following analysis will produce a range of maintenance costs that would allow the systems to remain cost effective. Actual costs are expected to be less than those calculated values.

There are no known maintenance costs associated with energy recovery systems. These systems were not studied.

2.9.8 Energy Cost Savings

Measure 1: Direct Replacement of Exhaust Air Limitation

The statewide energy cost savings associated with this measure were not modeled because the measure saves energy and reduces first cost and thus is immediately cost effective. However, the energy cost savings for a typical system over 15 years, using the 2011 energy cost data for CTZ 12 was calculated to be $6,435. Further detail is provided in the Sections 3 and 4. The test scenario described below demonstrates that savings are available in all cases.

Measure 2: Type I Exhaust Hood Airflow Limitations

The statewide energy cost savings associated with this measure were not modeled for all climate zones because the measure saves energy and reduces first cost and thus is immediately cost effective. However, for a typical system the annual electrical cost savings were calculated to be $1,523. Further detail is provided in the Sections 3 and 4. The test scenario described below demonstrates that savings are available in all cases.

Measure 3: Makeup and Transfer Air Requirements

The statewide energy cost savings associated with this measure were not modeled precisely for each climate zone because the measure saves energy and reduces first cost and thus is immediately cost effective. Energy cost savings depend primarily on the percent of transfer available and utilized by the system. This energy cost savings potential is shown in Figure 3, in Section 3.3. The test scenarios described below demonstrate that savings are available in all cases at least within climate zones representing the largest future commercial growth.

Measure 4: Commercial Kitchen System Efficiency Options

Measured energy costs savings varied widely based on system size, but ranged from about $2,000 per year to $22,000 per year. See the Analysis and Results section for additional discussion on the energy cost savings.

2.10 Analysis Tools

No tools were used to analyze the energy and cost savings of these measures. See the Analysis and Results section for further discussion.

2.11 Relationship to Other Measures

No other measures impact these measures.

3. Methodology

3.1 Measure 1: Direct Replacement of Exhaust Air Limitation

The economic justification for this measure was made by comparing equipment first cost and energy cost differences between an exhaust-only hood system versus an equivalently performing short-circuit hood system for a 10' section of cooking line. An exhaust-only hood provides adequate capture and containment in this hood section with 1,500 cfm of exhaust air. The replacement air is assumed to come from the room in both cases. An equivalently performing 10' short-circuit hood would have to exhaust 3,000 cfm with 1,500 cfm of replacement air being directly injected into the hood and the remaining 1,500 cfm coming from the room.

The basis of comparison used the costs of the hoods, the cost of the exhaust fans, and the cost of the addition makeup air unit required for the short-circuit system. The energy comparison used the brake horsepower difference between the exhaust and makeup air fans. The difference in brake horsepower was then converted to KW and multiplied by 15-year hourly energy cost data. The systems were assumed to operate from 11 am to 11 pm everyday to simulate a typical restaurant serving lunch and dinner. Climate Zone 12 was used as the source of the energy costs but the energy savings are not associated with climate and would apply to all climate zones. Other metrics like the amount of ductwork, fire-proofing insulation could also be compared but since there is no component of a short-circuit hood system that is smaller and thereby costs less over an exhaust-only hood system, the comparison is limited to this small set of essential equipment to justify the costs. Equipment cost data has been provided by a kitchen hood vendor.

1,500 CFM Exhaust Only Hood System		**3,000 CFM Short-circuit Hood**	
Hood Cost	$ 1,339	Hood Cost	$ 2,283
Exhaust Fan Cost	$ 700	Exhaust Fan Cost	$ 816
		Additional MUA Cost	$ 544
Total	$ 2,039	Total	$ 3,643
Cost Difference	$ 1,604		

Figure 1:Equipment First Cost Comparison

1,500 CFM Exhaust Only Hood System	BHP	**3,000 CFM Short-circuit Hood**	BHP
1,500 CFM Exhaust Only Hood	0.405	3,000 CFM Short-Circuit Ho(	0.935
		1,500 CFM MUA	0.302
Total	0.405	Total	1.237
BHP Difference	0.83 hp		

Figure 2: Incremental Fan Power

			Electricity			BHP Difference		0.832
			CTZ12	elec rate ($/kWh) (2011 Dataset)		KW Difference		0.620
Month	Day	Hour	TDV kBtu/kWh 0.084363 $/kBtu	$0.0843629	Hour of Operation (Y/N)	15-yearElectricity Cost ($)	Sum Electrical Cost	
1	1	1	16.55	1.47	N	-	$ 6,435.50	
1	1	2	15.99	1.42	N	-		
1	1	3	15.75	1.40	N	-		
1	1	4	15.65	1.39	N	-		
1	1	5	16.16	1.44	N	-		
1	1	6	18.14	1.61	N	-		
1	1	7	20.47	1.82	N	-		
1	1	8	20.7	1.84	N	-		
1	1	9	21.13	1.88	N	-		
1	1	10	20.63	1.84	N	-		
1	1	11	20.39	1.81	Y	1.1258		
1	1	12	20.4	1.82	Y	1.1264		
1	1	13	20.51	1.83	Y	1.1325		
1	1	14	20.51	1.83	Y	1.1325		
1	1	15	19.57	1.74	Y	1.0806		
1	1	16	19.92	1.77	Y	1.0999		
1	1	17	20.66	1.84	Y	1.1408		
1	1	18	20.54	1.83	Y	1.1341		
1	1	19	20.5	1.82	Y	1.1319		
1	1	20	20.54	1.83	Y	1.1341		
1	1	21	20.75	1.85	Y	1.1457		
1	1	22	20.57	1.83	Y	1.1358		
1	1	23	20.16	1.79	Y	1.1131		
1	1	24	18.76	1.67	N	-		

Figure 3: Sample Energy Cost Comparison

3.2 Measure 2: Type I Exhaust Hood Airflow Limitations

The cost justification for this measure compares two kitchen hood designs of equal capture and containment performance. The Base Case uses an unlisted hood sized to meet prescribed code minimum or ASHRAE Standard 154 exhaust rates. The Proposed Case uses a listed hood sized to meet 30% better than ASHRAE Standard 154 Rates listed in Table 1.

3.3 Measure 3: Makeup and Transfer Air Requirements

The economic justification for this measure was completed by comparing the energy and energy costs required to condition a kitchen over a range of transfer air percentages of kitchen exhaust air. These costs were graphed to illustrate the relative energy cost savings of using the maximum transfer air. This analysis used binned TMY3 weather data for three growing markets in California: Riverside, Sacramento, and San Francisco.

3.4 Measure 4: Commercial Kitchen System Efficiency Options

The cost effectiveness of demand control ventilation kitchen systems has been studied by the utility, Southern California Edison (SCE), who commissioned a study in 2009 which reviewed five commercial kitchen installations using DCV. The installations were all based on the Melink Intelli-hood system and included installation costs and exhaust fan energy savings only. Air conditioning energy savings were not studied. The installations represented different sectors of the market: smaller quick service restaurants and larger hotel and resort kitchens. The results of their study are used here to justify the cost effectiveness of DCV system as a design option for this measure.

3.5 Statewide Energy Savings

The statewide energy savings associated with the proposed measures were calculated by multiplying the per unit estimate with the statewide estimate of new construction in 2014. The new construction forecast was derived from a study Southern California Edison’s Food Service Technology Center performed (SCE 2009).

4. Analysis and Results

4.1 Measure 1: Direct Replacement of Exhaust Air Limitation

The equipment cost for the measure case based on an exhaust-only hood system described in the test scenario is $1,604 less than an equivalently performing short-circuit hood system in the base case when comparing the hoods, exhaust fans, and makeup air units.

The energy cost difference between the two systems over 15 years using the 2011 energy data for CTZ 12 is $6,435.

As demonstrated, there is no performance or economic benefit associated with short-circuit hood systems when compared to exhaust-only hood systems.

The proposal allows 10% direct replacement to allow hood manufacturers to employ different capture and containment strategies that resemble short-circuit hoods but do not have the performance deficiencies of short-circuit hoods. Systems that use less than 10% direct replacement include the Halton Capture Jet, which has been tested by the PG&E Food Service Technology Center and shown to provide equal or better C&C compared to an exhaust-only hood with the exhaust flow rate.

4.2 Measure 2: Type I Exhaust Hood Airflow Limitations

Equipment and electrical costs of each case were compared. Only the hoods, exhaust fans, and makeup fans were used. Similar comparisons could include differences in duct sizes, diffuser size and counts, and the conditioning energy. As these additional comparisons would reveal the same differences as the values used, they were not included.

Table 2 below compares the equipment costs between an exhaust and makeup air system using an unlisted hood versus a listed hood. The unlisted 10' canopy wall hood for heavy duty used requires an exhaust rate of 550 cfm per linear foot of the leading edge of the hood. A similar listed hood requires an exhaust rate of 385 cfm per linear foot. The hood costs per the vendor we consulted are the same. The explanation for this is that the hoods have similar amounts of sheet metal and require similar amounts of labor to construct. The only difference between them is the vendor's expense to test their hood designs for listing. It was explained that most cataloged commercial hoods are listed which creates cost competition so there is no economic benefit to pursue an unlisted hood. The exhaust fans and makeup air fans cost data reflect fans sized for the specific hood cfm. In the scenario developed, there is a $5,676 difference in the equipment.

Table 3 below compares the power and electrical costs to exhaust and makeup the different air rates. The electrical costs assumed 5,400 hours of operation a year and an average electrical rate of $0.15 per kilowatt-hour. The annual electrical cost difference between the systems is $1,523.

The data shows that listed hoods cost the same as unlisted hoods but the fans cost more for system with the higher exhaust rate. Subsequent, the energy costs are also more for the system with the higher exhaust rate.

	Exhaust Hood CFM	Exhaust Hood Cost	Exhaust Fan Cost	Makeup Unit Cost	Net Cost
Unlisted Hood System, ASHRAE Std 154	5,550	$1,300	$2,090	$16,830	**$20,220**
Listed Hood System, 30% Better than Std 154	3,850	$1,300	$1,463	$11,781	**$14,544**

Figure 4: Hood and Fan Cost Comparison

	Exhaust Hood CFM	Exhaust Hood HP	Makeup Unit HP	Annual **Electrical Costs**
Unlisted Hood System, ASHRAE Std 154	5,500	2.98	4.37	**$3,552**
Listed Hood System, 30% Better than Std 154	3,850	2.32	1.88	**$2,029**

Figure 4: Hood and Fan Power Comparison

4.3 Measure 3: Makeup and Transfer Air Requirements

A scenario describing a typical kitchen/dining room design was developed as the basis of comparison for the range of transfer air ratios in different climates. The scenario uses the following assumptions:

- 1,000 square foot commercial kitchen
- 10,000 cfm exhaust hood
- Cooling supply airflow: 2,000 cfm or 80% of the exhaust cfm
- Supply air temperature was to 55°F
- Space temperature setpoint, return air, and transfer air temperatures were set to 70°F
- Cooling load of 9.5 w/sf
- $0.12/Kwh Electrical Rate
- $1/therm Gas Rate
- 0.0005 KW/cfm fan energy use
- 1 Kw/ton cooling equipment efficiency
- 0.70 thermal efficiency for gas heating equipment
- Hour of operation: 6am to 10pm daily for a total of 5,838 hours per year.

A spreadsheet was created that used these assumptions to calculate the costs associated with fan energy, cooling energy, and heating energy over a year using 5°F bin weather data. The weather data was filtered to only the number of hours in each temperature bin within the 6am to 10pm hours of operation. The annual energy costs were tabulated over the range of available transfer air percentages. Low transfer air percentages represent higher amounts outside makeup air that must be conditioned. High transfer air represents lower amounts of outside makeup air.

Figure 5 is a graph of the energy cost data for the model kitchen described above in the three climate zones studied at all fractions of transfer air to exhaust airflow rates. Assumed average energy rates were used to demonstrate the energy cost relationships of the same system in different climates which is irrespective of the energy rate used.

The highest energy costs are associated with 0% transfer air represent conditioning 100% of the exhaust replacement air. This is the type of system design this measure attempts to minimize. As the amount of transfer air is increased, the associated costs to condition excessive amounts of outside air are reduced.

The cost data for the Percent of Transfer equal to 80% corresponds to the space cooling supply airflow of 2,000 cfm. It is noted that the transfer percentages greater than 80% may produce more annual savings and remains a design option. Higher amounts of transfer air than the percent of {Cooling CFM/Exhaust CFM} requires that the makeup air unit have the ability to use return air. A unit with the ability to use return air may be more expensive and complicated to control than a 100% outdoor air unit, the cost of which would offset the marginal economic benefit of using more transfer air. This system design option is allowed by the proposed code.

The case where 100% of the exhaust air replacement is available as transfer air allows the designer to use a recirculating conditioning unit without any outside air. This type of system is allowed by the code although it does use slightly more energy than a system using some outside air. This increased energy for 100% transfer systems is attributed to the loss of any free economizer cooling of which there are many available hours in California.

The transfer air percentage equal to {Cooling CFM/Exhaust CFM} appears to be a reasonable limitation for all California climate zones to take maximum advantage of economizer cooling with relatively simple and inexpensive equipment and equipment controls.

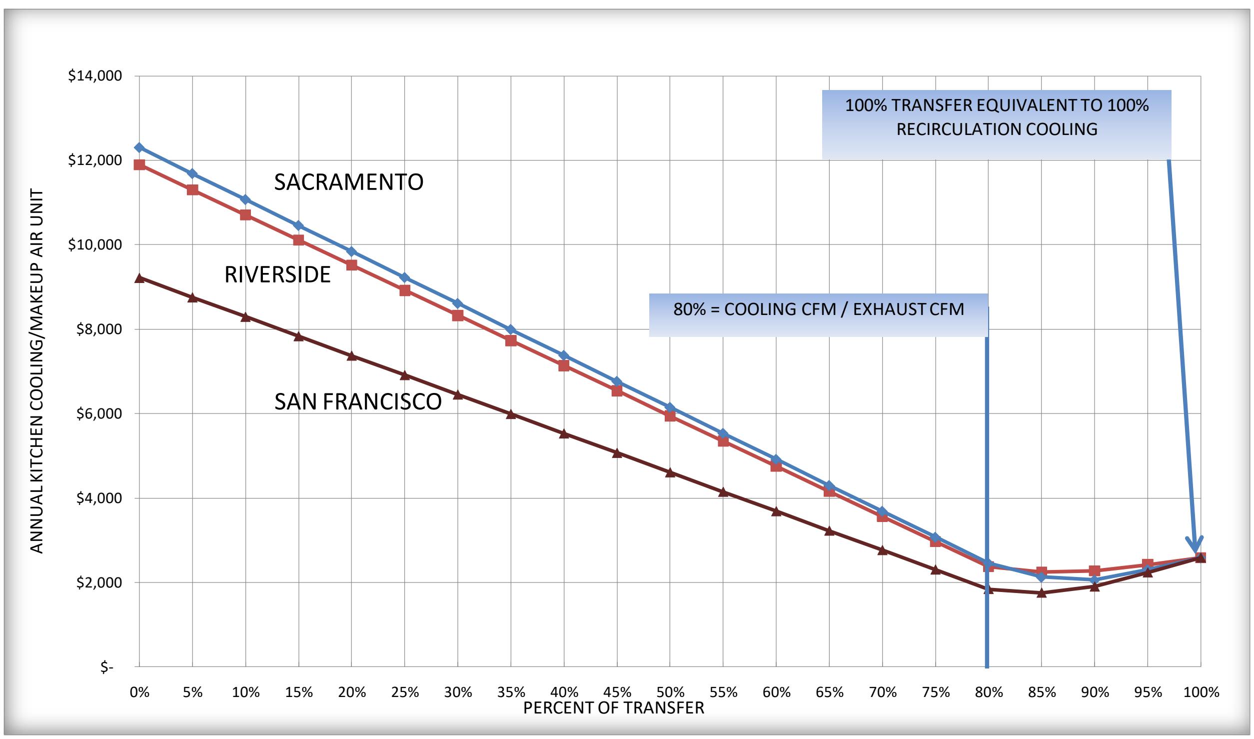


Figure 5: Graph of Annual Energy Costs Relative to Percent of Transfer

The following figures graphically illustrate systems that do and do not comply with this measure.

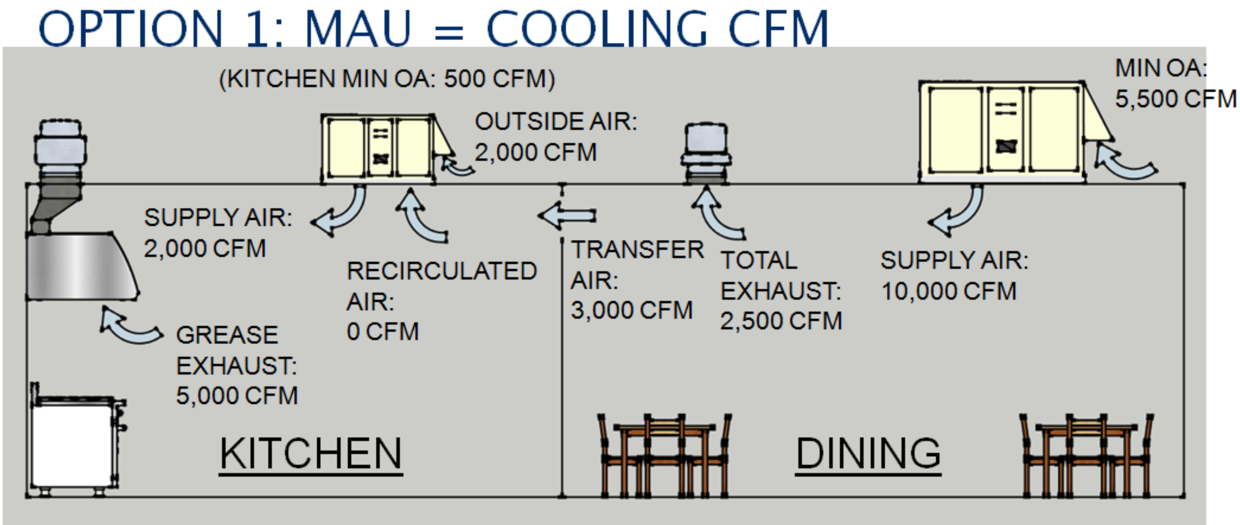


Figure 6: Design Option 1: Makeup Air Equals Cooling CFM

Figure 6 illustrates the system described in the scenario above where the kitchen cooling load is 2,000 cfm and is provided by a dedicated makeup air unit that does not recirculate any air. The balance of makeup air is provided from the Dining area zone. The unit serving the Dining unit brings in outside air to satisfy the Dining zone ventilation requirements. General exhaust requirement such as bathrooms only exhaust 2,500 cfm of the total ventilation 5,500 cfm. 3,000 cfm of air would other have to be relieved from the space. By transferring this air resource into the kitchen, energy is conserved from otherwise conditioning more outside air. Kitchen ventilation requirements are provided by the kitchen unit.

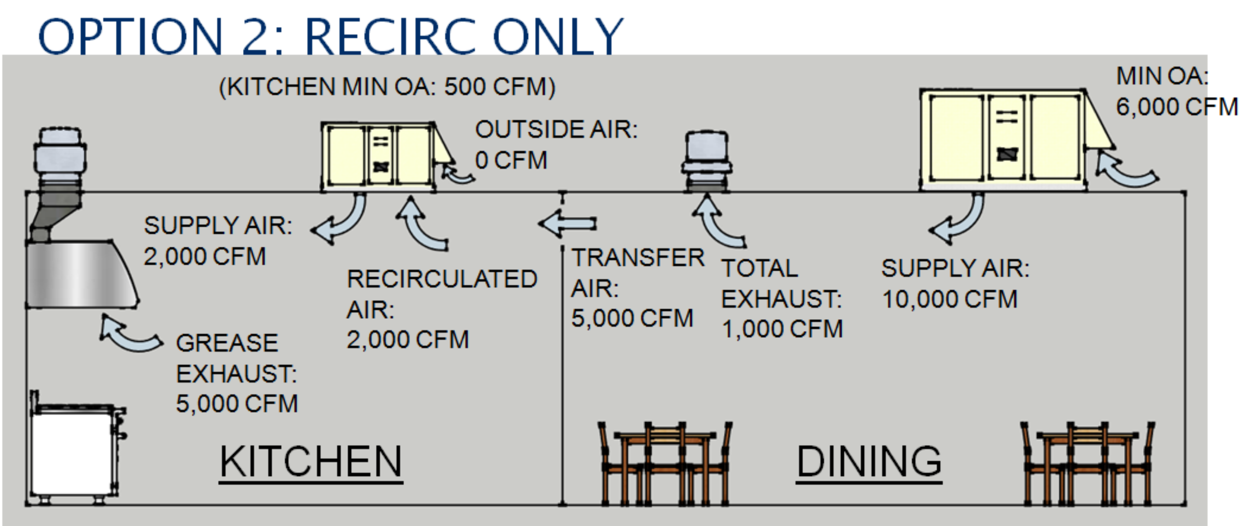


Figure 7: Design Option 2: Makeup Air Equals 100% Transfer, Cooling is 100% Recirculation

Figure 7 illustrates the condition in the graph of Figure 5 where 100% of transfer air is used as makeup air. The unit serving the kitchen still has a cooling load of 2,000 cfm but now must recirculate 100% of the air. As the kitchen unit does not introduce any ventilation air, the kitchen ventilation air must be provided by the Dining unit. Consequently, this unit requires more outside air. This scenario per the graph on Figure 5 uses slightly more energy than Design Option 1 in Figure 6 but not significantly.

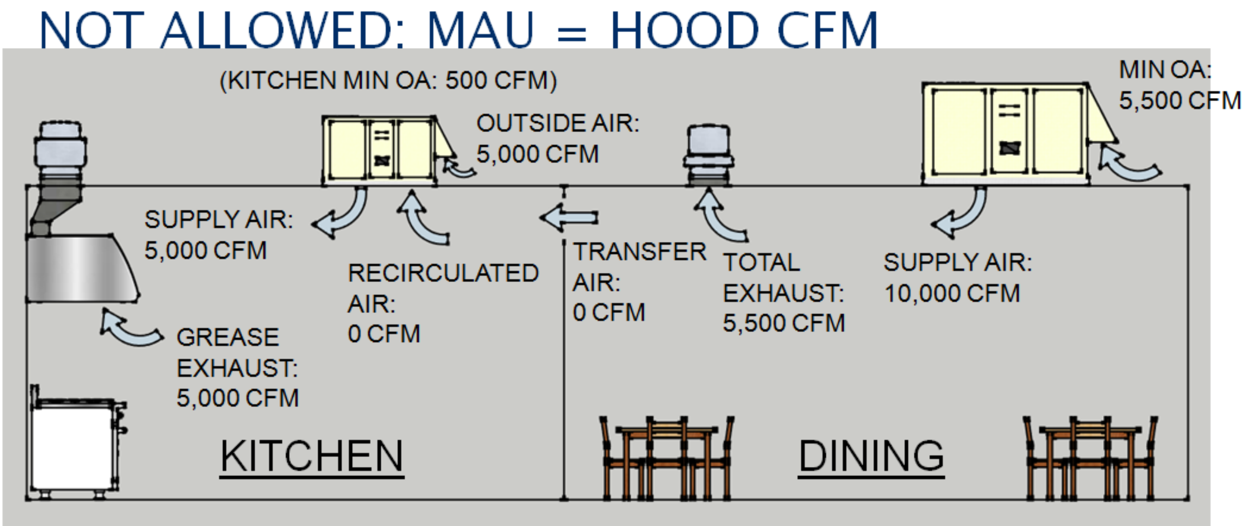


Figure 8: Disallowed Design Option: Makeup Air Equals Exhaust CFM

Figure 8 illustrates the type of system this measure intends to discourage. The system has a kitchen unit that provides 100% of the hood exhaust while available transfer air is being exhausted out of adjacent spaces. This is a wasteful practice because the units are conditioning larger amounts of outside air than the other system design options described above.

4.4 Measure 4: Commercial Kitchen System Efficiency Options

Figure 9 below summarizes the data collected in the study by SCE of five different DCV installations.

	El Pollo Loco (Quick, Retrofit)	Panda Express (Quick, New Constr.)	Farmer Boys (Quick, New Constr.)	Desert Springs Marriot (Hotel, Retrofit)	Westin Mission Hills (Hotel, Retrofit)
Total Exhaust, CFM	7,760	6,000	6,500	23,914	21,954
Installation Costs ($)	$15,500	$8,000	$9,000	$28,000	$22,000
Annual Fan Energy Saved kWh/year	9,871	15,061	7,884	150,189	60,439
Annual Fan Energy Cost Savings (Avg. $0.15/kWh)	$1,481	$2,259	$1,183	$22,528	$9,066
Simple Payback (Years) (Excl Maintenance/Heating/Cooling)	10.47	3.54	7.61	1.24	2.43

Figure 9: Study Data and Payback Period Excluding Maintenance Costs or Heating/Cooling Savings

The study used an average energy cost of $0.15. Simple payback calculations used this average energy cost applied to the measured energy savings but did not include maintenance costs or the energy savings associated with heating or cooling makeup air.

The shortest payback periods were associated with new construction installations and installations with high fan horsepower systems and high cooking demand diversity. New construction is typically less costly than retrofit installations because of the complexities associated with retrofits. Systems with high horsepower motors and high demand diversity experience the largest savings because of extended periods when large fan systems operate at lower speeds under low cooking demand. Figure 10 below demonstrates the daily electrical power demand for an exhaust fan for one of the hotels installations. The BLACK curve shows the power used by this fan which operates 24 hours per day without any speed control. The RED curve shows the power required when the fan was modulated to the cooking demand under the hood. The GREEN line is the daily average of the RED curve and represents a 46% reduction in daily power demand.

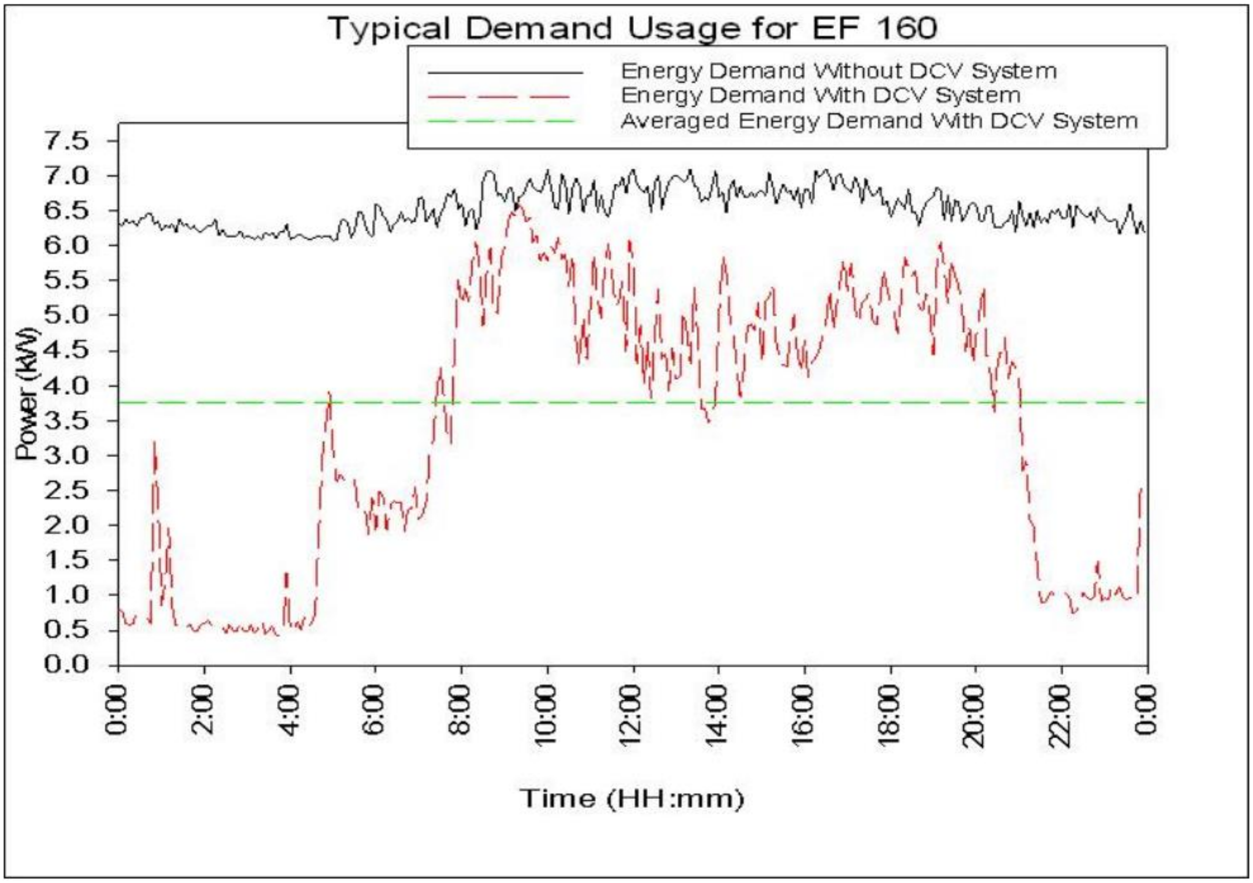


Figure 10: Example of an Exhaust Fan Daily Power Demand With and Without DCV

The longest payback period of all the study sites is associated with the El Pollo facility which is attributed to the project being a retrofit installation of a low fan horsepower system and low diversity. This facility had relative little cooking demand diversity associated throughout a typical operating day as shown in Figure 11. However, a DCV system did save enough energy through reduce fan power alone to pay for the system in a reasonable time period. If conditioned makeup air savings were included then the payback is conceivably less.

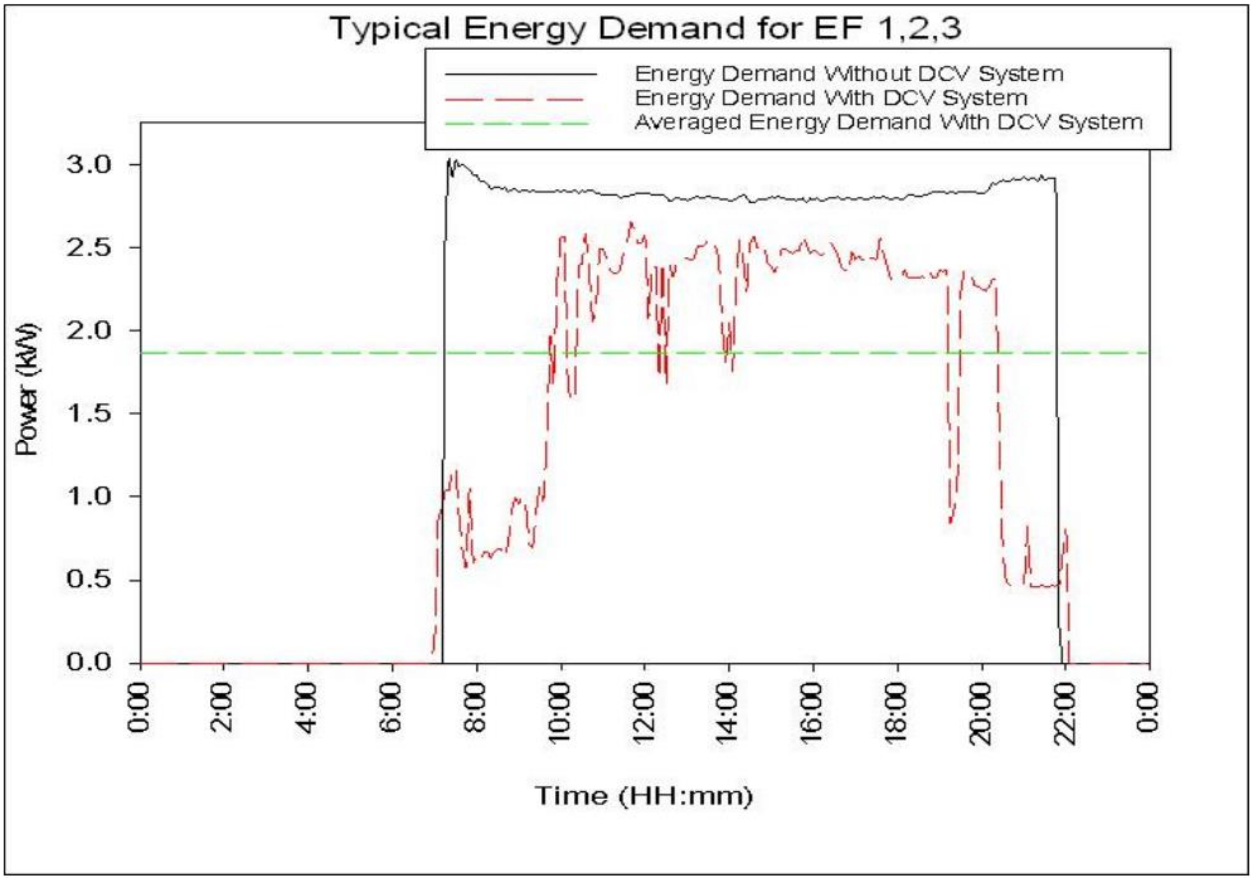


Figure 11: Typical Demand Usage for El Pollo Kitchen Exhaust Fan Systems

To examine the life cycle costs of the case study installations an average 15-year TDV energy cost was calculated assuming daily operation from 9 am to 12 midnight in Climate Zone 11 using the 2010 TDV tables. Climate zone 11 was used because the study sites were located in this region. The average TDV rate for these conditions is $0.17. Figure 12 below includes the annual energy savings using this average cost. Also, included are adjusted installation cost estimates assuming the same installations were new construction and performed in a time when the technology is more mature and prevalent in the market due to code requirements and natural market growth. Annual maintenance costs were estimated with the assistance of a vendors and contractors as the product of 30 minutes of service at $100/hr performed quarterly. The simple payback periods for all installations in the case study including maintenance and reduced installation costs are less than 9.10 years.

	El Pollo Loco (Quick, Retrofit)	Panda Express (Quick, New Constr.)	Farmer Boys (Quick, New Constr.)	Desert Springs Marriot (Hotel, Retrofit)	Westin Mission Hills (Hotel, Retrofit)
Installation Costs ($)	$15,500	$8,000	$9,000	$28,000	$22,000
Annual Fan Energy Cost Savings (Avg.TDV $0.17/kWh)	$1,678	$2,560	$1,340	$25,532	$10,275
Est. Installation Costs for New Const. & Mature Technology	$11,625	$6,800	$7,650	$21,000	$16,500
Annual Maintenance Costs ($)	$400	$400	$600	$1,200	$600
Simple Payback Inc Maintenance (Years)	9.10	3.15	10.33	0.86	1.71

Figure 12: Life Cycle Costs for Case Study Installations

4.5 Statewide Savings Estimates

4.5.1 Measure 1: Direct Replacement of Exhaust Air Limitation

No significant per unit or statewide energy savings.

4.5.2 Measure 2: Type I Exhaust Hood Airflow Limitations

The total energy and energy cost savings potential for this measure are 0.78 W/SF, and 4.21 kWh/SF. Applying these unit estimates to the statewide estimate of new construction of 2.314 million square feet per year results in first year statewide energy savings of 1.803 MW, and 9.74 GWh.

4.5.3 Measure 3: Makeup and Transfer Air Requirements

The total energy and energy cost savings potential for this measure are 1.37 W/SF, 8.02 kWh/SF, and 0.08 therms/SF. Applying these unit estimates to the statewide estimate of new construction of 2.314 million square feet per year results in first year statewide energy savings of 3.18 MW, 18.55 GWh, and 192,150 therms.

4.5.4 Measure 4: Commercial Kitchen System Efficiency Options

The total energy and energy cost savings potential for this measure are 5.36 W/SF, and 31.11 kWh/SF. Applying these unit estimates to the statewide estimate of new construction of 2.314 million square feet per year results in first year statewide energy savings of 12.41 MW, 72.0 GWh, and 741,600 therms.

5. Stakeholder Input

To the extent possible, explain the key issues discussed and key concerns raised by stakeholders.

5.1 Measure 1: Direct Replacement of Exhaust Air Limitation

No issues were raised in Stakeholder meetings regarding this measure.

5.2 Measure 2: Type I Exhaust Hood Airflow Limitations

No issues were raised in Stakeholder meetings regarding this measure.

5.3 Measure 3: Makeup and Transfer Air Requirements

Members of CAL OSHA who attended stakeholder meetings expressed concerns about maintaining minimum ventilation in kitchens in system designs that use high rates of transfer air usage approaching 100%. If kitchen ventilation is provided via 100% transfer air from other spaces, the air handlers serving those spaces must include enough outside air to serve the kitchen too. Otherwise, ventilation shall be provided via direct makeup air units. It remains the designer's responsibility to ensure ventilation is provided. This is stated explicity in the following section of Title 24:

> **EXCEPTION to Section 121(b)2:** Transfer air. The rate of outdoor air required by Section 121(b)2 may be provided with air transferred from other ventilated spaces if:
>
> A. None of the spaces from which air is transferred have any unusual sources of indoor air contaminants; and
>
> B. The outdoor air that is supplied to all spaces combined, is sufficient to meet the requirements of Section 121(b)2 for each space individually.

5.4 Measure 4: Commercial Kitchen System Efficiency Options

Members of CAL OSHA who attended stakeholder meetings raised some key issues which stimulated the addition of the following requirements for demand controlled systems:

1) Demand controlled systems shall include failsafe controls that result in full flow upon cooking sensor failure
2) Demand controlled systems shall allow occupants the ability to temporarily override the system to full flow
3) Demand controlled systems shall be capable of reducing exhaust and replacement air system airflow rates to the larger of:
    a. 50% of the total design exhaust and replacement air system airflow rates
    b. The ventilation rate required per Section 121

All of these additions addressed a concern for kitchen occupants to be provided minimum ventilation and provisions for maintaining a safe environment in the event of a hood control failure.

6. Recommended Language for the Standards Document, ACM Manuals, and the Reference Appendices

6.1 Measure 1: Direct Replacement of Exhaust Air Limitation

6.1.1 SECTION 101 – DEFINITIONS AND RULES OF CONSTRUCTION

6.1.2 SECTION 144 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

(m) **Limitation on Direct Replacement of Kitchen Hood Exhaust Air**. Replacement air introduced directly into the hood cavity of kitchen exhaust hoods shall not exceed 10% of the hood exhaust airflow rate.

6.1.3 Nonresidential ACM Manual

There are no ACM modeling rules associated with this measure.

6.2 Measure 2: Type I Exhaust Hood Airflow Limitations

6.2.1 SECTION 144 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

(o) **Type I Exhaust Hood Airflow Limitations**. For kitchen/dining facilities having total Type 1 and Type II kitchen hood exhaust airflow rates greater than 5,000 cfm, each Type 1 hood shall have an exhaust rate that complies with Table 1. If a single hood, or hood section, is installed over appliances with different duty ratings, then the maximum allowable flow rate for the hood or hood section shall not exceed the Table 1 values for the highest appliance duty rating under the hood or hood section. Refer to the ASHRAE Standard 154 for definitions of hood type, appliance duty, and net exhaust flow rate.

Table 144-C Maximum Net Exhaust Flow Rate, CFM per Linear Foot of Hood Length

Type of Hood	Light Duty Equipment	Medium Duty Equipment	Heavy Duty Equipment	Extra Heavy Duty Equipment
Wall-mounted Canopy	140	210	280	385
Single Island	280	350	420	490
Double Island	175	210	280	385
Eyebrow	175	175	Not Allowed	Not Allowed
Backshelf/Pass-over	210	210	280	Not Allowed

Exceptions:

a) 75% of the total Type I and Type II exhaust replacement air is transfer air that would otherwise be exhausted.

6.2.2 Nonresidential ACM Manual

Refer to Section 5.5 for Nonresidential ACM language.

6.3 Measure 3: Makeup and Transfer Air Requirements

6.3.1 SECTION 101 – DEFINITIONS AND RULES OF CONSTRUCTION

101 (b) Definitions.

Makeup Air (Dedicated Replacement Air): outdoor air deliberately brought into the building from the outside and supplied to the vicinity of an exhaust hood to replace air, vapor, and contaminants being exhausted. Makeup air is generally filtered and fan-forced, and it may be heated or cooled depending on the requirements of the application. Makeup air may be delivered through outlets integral to the exhaust hood or through outlets in the same room.

Replacement Air: outdoor air that is used to replace air removed from a building through an exhaust system. Replacement air may be derived from one or more of the following: makeup air, supply air, transfer air, and infiltration. However, the ultimate source of all replacement air is outdoor air. When replacement air exceeds exhaust, the result is exfiltration.

Transfer Air: air transferred from one room to another through openings in the room envelope, whether it is transferred intentionally or not. The driving force for transfer air is generally a small pressure differential between the rooms, although one or more fans may be used.

6.3.2 SECTION 144 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

(n) **Kitchen Ventilation – Makeup and Transfer Air** Mechanically cooled or heated makeup air delivered to any space with a kitchen hood shall not exceed the greater of:

a) The supply flow required to meet the space heating and cooling load
b) The hood exhaust flow minus the available transfer air from adjacent spaces.

Available transfer air is that portion of outdoor ventilation air serving adjacent spaces not required to satisfy other exhaust needs, such as restrooms, not required to maintain pressurization of adjacent spaces, and that would otherwise be relieved from the building.

6.3.3 Nonresidential ACM Manual

Refer to Section 5.5 for Nonresidential ACM language.

6.4 Measure 4: Commercial Kitchen System Efficiency Options

6.4.1 SECTION 125 – REQUIRED NONRESIDENTIAL MECHANICAL SYSTEM ACCEPTANCE

15. Type I Kitchen Hoods shall be tested in accordance with NJ.16.1.

6.4.2 SECTION 144 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

(p) Kitchen Ventilation – Efficiency Options. A kitchen/dining facility having a total Type I and Type II kitchen hood exhaust airflow rate greater than 5,000 cfm shall have one of the following:

a) At least 50% of all replacement air is transfer air that would otherwise be exhausted.
b) Demand ventilation system(s) on at least 75% of the exhaust air. Such systems shall:
    1) Include controls necessary to modulate airflow in response to appliance operation and to maintain full capture and containment of smoke, effluent and combustion products during cooking and idle
    2) Include failsafe controls that result in full flow upon cooking sensor failure
    3) Allow occupants the ability to temporarily override the system to full flow
    4) Be capable of reducing exhaust and replacement air system airflow rates to the larger of:
        i. 50% of the total design exhaust and replacement air system airflow rates
        ii. The ventilation rate required per Section 121
c) Listed energy recovery devices with a sensible heat recovery effectiveness of not less than 40% on at least 50% of the total exhaust airflow.
d) A minimum of 75% of makeup air volume that is:
    a. Unheated or heated to no more than 60°F
    b. Uncooled or cooled without the use of mechanical cooling

6.4.3 NR & R APPENDICES – NA7.5.15 (Functional Tests)

The following shall be added to the NR Compliance Manual in the NA7 section

NA7.5.15 Kitchen Exhaust Systems with Type I Hood Systems

The following acceptance tests apply to commercial kitchen exhaust systems with Type I exhaust hoods. All Type I exhaust hoods used in commercial kitchens shall be tested.

NA7.5.15.1 Kitchen Exhaust Construction Inspection

1. Verify exhaust and replacement air systems are installed, power is installed and control systems such as demand control ventilation are calibrated
2. For kitchen/dining facilities having total Type 1 and Type II kitchen hood exhaust airflow rates greater than 5,000 cfm, calculate the maximum allowable exhaust rate for each Type 1 hood per Table 144-C.

NA7.5.15.2.1 Functional Testing - Full Load Conditions

The following acceptance test applies to systems with and without demand control ventilation exhaust systems.

1. Operate all sources of outdoor air providing replacement air for the hoods
2. Operate all sources of recirculated air providing conditioning for the space in which the hoods are located
3. Operate all appliances under the hoods at operating temperatures
4. Verify that the thermal plume and smoke is completely captured and contained within each hood at full load conditions by observing smoke or steam produced by actual cooking

operation and/or by visually seeding the thermal plume using devices such as smoke candles or smoke puffers. Smoke bombs shall not be used (note: smoke bombs typically create a large volume of effluent from a point source and do not necessarily confirm whether the cooking effluent is being captured). For some appliances (e.g., broilers, griddles, fryers), actual cooking at the normal production rate is a reliable method of generating smoke). Other appliances that typically generate hot moist air without smoke (e.g., ovens, steamers) need seeding of the thermal plume with artificial smoke to verify capture and containment.

5. Verify that space pressurization is appropriate (e.g. kitchen is slightly negative relative to adjacent spaces and all doors open/close properly).
6. Verify that each Type 1 hood has an exhaust rate that is below the maximum allowed.
7. Make adjustments as necessary until full capture and containment and adequate space pressurization are achieved and maximum allowable exhaust rates are not exceeded. Adjustments may include:
    a. adjust exhaust hood airflow rates
    b. add hood side panels
    c. Add rear seal (back plate)
    d. Increase hood overhang by pushing equipment back
    e. Relocate supply outlets to improve the capture and containment performance
8. Measure and record final exhaust airflow rate per Type 1 hood.

NA7.5.15.2.2 Functional Testing - Exhaust Systems with Demand Control Ventilation

The following additional acceptance test shall be performed on all hoods with demand control ventilation exhaust systems.

1. Turn off all kitchen hoods, makeup air and transfer systems
2. Turn on one of the appliances on the line and bring to operating temperature. Confirm that:
    a. DCV system automatically switches from off to the minimum flow setpoint.
    b. The minimum flow setpoint does not exceed the larger of
        i. 50% of the design flow, or
        ii. the ventilation rate required per Section 121.
    c. The makeup air and transfer air system flow rates modulate as appropriate to match the exhaust rate
    d. Appropriate space pressurization is maintained.
3. Operate all appliances at typical conditions. Apply sample cooking products and/or utilize smoke puffers as appropriate. Confirm that:
    a. DCV system automatically ramps to full speed.
    b. Hood maintains full capture and containment during ramping to and at full-speed
    c. Appropriate space pressurization is maintained.

6.5 Nonresidential ACM Manual

Kitchen Space Type: In order for compliance software to analyze this and other kitchen related measures, kitchens shall be modeled as separate space types apart from other building occupancy types and be assigned lighting, plug load, and people densities. Internal load shall use the following:

- Lighting: 1.6 watts per square foot
- Plug Load: 10 watts per square foot
- Occupants: 100 square feet per occupant
- Schedules: Use Table N2-8-Nonresidential Occpancy Schedules(Other than Retail)

User Input:

1. Values for all Type I and Type II exhaust hoods in the modeled kitchen.
   a. CFM values for all hoods
   b. For Type I hoods ONLY
      i. Hood Length
      ii. Hood Style (Canopy, Wall Mount, etc.)
      iii. Hood Cooking Duty (Highest duty appliance under hood)

The Standard Baseline Model:

1. Total kitchen exhaust shall be either:
   a) If the total exhaust is less than 5,000 cfm, the user entered total exhaust rate.
   b) If the total exhaust rate is greater than or equal to 5,000 cfm, a total exhaust rate that is the sum of the Type I hoods based on the user input data and less than or equal to the maximum net exhaust flow rate in Table 144-C.
   c) Hood exhaust total static pressure shall be 2.5" and the fan efficiency shall be 50%.
2. Conditioning Systems
   a. The Cooling Load and Cooling CFM for the kitchen are calculated using a Cooling Space Setpoint of 80°F and a Cooling Supply Air temperature setpoint of 60°F.
   b. The standard model shall use a 100% outside air direct evaporative system if the space temperature exceeds 80°F less than 10 hour per year, i.e. the compliance software will have to first run direct evaporative and then run DX if direct evaporative cannot meet the comfort criteria.
      i. Direct evaporative system assumptions:
         1. 90% direct evaporative effectiveness
         2. 1.5" total fan static, 60% fan efficiency
         3. 100% outside airflow equal to the total kitchen exhaust
   c. If the standard model cannot meet the direct evaporative criteria, the system shall be modeled as System 1 or 2 except as noted herein:
      i. The standard model shall model the makeup air unit as a 100% outside air packaged unit
      ii. Supply cfm shall use the larger of the Cooling CFM or the Total Exhaust minus the Available Transfer.
      iii. Total fan static for the packaged unit shall be 2.0" , fan efficiency shall be 50%.
   d. If the standard model cannot meet the direct evaporative criteria and the available transfer airflow is less than 50% of the total exhaust airflow, a DCV system shall be modeled.

i. The Standard model shall divide the total exhaust into two fans. One fan shall be 75% of the total and be demand controlled. The other fan shall be 25% of the total and be continuous speed controlled.

1. The 75% DCV controlled fan shall modulate airflow or speed based on the following daily FRACTIONAL schedule. Fan power fraction = speed fraction ^3.

Hour	Fraction		Hour	Fraction		Hour	Fraction
1	0.0		9	0.5		17	0.5
2	0.0		10	1.0		18	1.0
3	0.0		11	0.5		19	0.5
4	0.0		12	1.0		20	0.00
5	0.0		13	0.5		21	0.00
6	0.0		14	1.0		22	0.00
7	0.5		15	0.5		23	0.00
8	0.5		16	1.0		24	0.00

2. The 25% constant speed fan shall use a typical T24 ON/OFF schedule or 0%//100% FRACTIONAL schedule.

3. Transfer Air
   a. Available transfer shall be calculated from the building minimum outside airflow less any exhaust airflows (not including the kitchen exhausts) and 0.05 cfm/sf for exfiltration.
4. Schedules
   a. Exhaust fans and makeup air units shall use either the DCV FRACTIONAL schedule or the ON/OFF schedule applied as appropriate for the entered fan control.

7. Bibliography and Other Research

ANSI/ASHRAE Standard 154-2003, Ventilation for Commercial Cooking Operations.

ASHRAE 1202-RP, Effect of Appliance Diversity and Position on Commercial Kitchen Hood Performance.

California Building Standards Commission. 2007. Title 24 California Mechanical Code, California Code of Regulations, Part 4.

Public Interest Energy Research(PIER). 2002. "Makeup air effects on commercial kitchen exhaust system performance (CEC P500-03-007F)." Grant Brohard, PG&E; Richard Swierczyna, Paul Sobiski, Vernon Smith, AEC; Donald Fisher, Fisher-Nickel, Inc.

[SCE] Southern California Edison. June 30, 2009. "Demand Control Ventilation for Commercial Kitchen Hoods (ET 07.10 Report)" Design & Engineering Services Customer Service Business Unit – Southern California Edison

8. Appendices

8.1 Appendix A: Measure 3: Makeup and Transfer Air Requirements

8.1.1 TEST SCENARIO DATA FOR RIVERSIDE

Riverside

% Transfer Air	80.00%	
Electric Rates	$0.12	per Kwh
Gas Rates	$1	per Therm
Fan KW/CFM	0.000497	KW/CFM
Cooling Efficiency	1	Kw/ton
Heating Efficiency	0.7	thermal efficiency
RAT	70	F
Exhaust Air	10000	cfm

OAT	RAT	OA CFM	RA CFM	MAT CFM	MAT
25	70	2000	0	2000	25
30	70	2000	0	2000	30
35	70	2000	0	2000	35
40	70	2000	0	2000	40
45	70	2000	0	2000	45
50	70	2000	0	2000	50
55	70	2000	0	2000	55
60	70	2000	0	2000	60
65	70	2000	0	2000	65
70	70	2000	0	2000	70
75	70	2000	0	2000	75
80	70	2000	0	2000	80
85	70	2000	0	2000	85
90	70	2000	0	2000	90
95	70	2000	0	2000	95
100	70	2000	0	2000	100

Free Cooling				Mechanical Cooling			Heating		
DT	Btuh	Fan KW	Cost per Hour	DT	Btuh	Cost Per Hour	DT	Btuh	Cost per Hour
15.0	32422	0.9943	($0.12)	0.0	0	$0.00	-30.0	-64778	($0.93)
15.0	32422	0.9943	($0.12)	0.0	0	$0.00	-25.0	-53978	($0.77)
15.0	32422	0.9943	($0.12)	0.0	0	$0.00	-20.0	-43178	($0.62)
15.0	32422	0.9943	($0.12)	0.0	0	$0.00	-15.0	-32378	($0.46)
15.0	32422	0.9943	($0.12)	0.0	0	$0.00	-10.0	-21578	($0.31)
15.0	32422	0.9943	($0.12)	0.0	0	$0.00	-5.0	-10778	($0.15)
15.0	32400	0.9943	($0.12)	0.0	-22	($0.00)	0.0	0	$0.00
10.0	21600	0.9943	($0.12)	-5.0	-10822	($0.11)	0.0	0	$0.00
5.0	10800	0.9943	($0.12)	-10.0	-21622	($0.22)	0.0	0	$0.00
0.0	0	0.9943	($0.12)	-15.0	-32422	($0.32)	0.0	0	$0.00
0.0	0	0.9943	($0.12)	-20.0	-43222	($0.43)	0.0	0	$0.00
0.0	0	0.9943	($0.12)	-25.0	-54022	($0.54)	0.0	0	$0.00
0.0	0	0.9943	($0.12)	-30.0	-64822	($0.65)	0.0	0	$0.00
0.0	0	0.9943	($0.12)	-35.0	-75622	($0.76)	0.0	0	$0.00
0.0	0	0.9943	($0.12)	-40.0	-86422	($0.86)	0.0	0	$0.00
0.0	0	0.9943	($0.12)	-45.0	-97222	($0.97)	0.0	0	$0.00

NET BTUH	NET Costs per Hour	Bin Hours 6am-10pm	Annual BTU's	Annual Costs
($32,357)	($1.04)	2	-64,714	-$2.09
($21,557)	($0.89)	12	-258,682	-$10.69
($10,757)	($0.74)	53	-570,110	-$39.02
$43	($0.58)	129	5,573	-$75.06
$10,843	($0.43)	291	3,155,371	-$124.42
$21,643	($0.27)	444	9,609,581	-$121.34
$32,378	($0.12)	834	27,003,586	-$99.69
$10,778	($0.23)	1090	11,748,456	-$248.01
($10,822)	($0.34)	794	-8,592,350	-$266.41
($32,422)	($0.44)	525	-17,021,340	-$232.85
($43,222)	($0.55)	539	-23,296,442	-$297.27
($54,022)	($0.66)	469	-25,336,130	-$309.32
($64,822)	($0.77)	347	-22,493,095	-$266.33
($75,622)	($0.88)	195	-14,746,212	-$170.73
($86,422)	($0.98)	78	-6,740,885	-$76.72
($97,222)	($1.09)	38	-3,694,421	-$41.48
		5838	-71,227,102	-$2,379.32
		Annual Hours, TM	Total BTU's Used	Annual Energy Cost

8.1.2 TEST SCENARIO DATA FOR SACRAMENTO

Sacramento

% Transfer Air	80.00%	
Electric Rates	$0.12	per Kwh
Gas Rates	$1	per Therm
Fan KW/CFM	0.000497	KW/CFM
Cooling Efficiency	1	Kw/ton
Heating Efficiency	0.7	thermal efficiency
RAT	70	F
Exhaust Air	10000	cfm

OAT	RAT	OA CFM	RA CFM	MAT CFM	MAT
25	70	2000	0	2000	25
30	70	2000	0	2000	30
35	70	2000	0	2000	35
40	70	2000	0	2000	40
45	70	2000	0	2000	45
50	70	2000	0	2000	50
55	70	2000	0	2000	55
60	70	2000	0	2000	60
65	70	2000	0	2000	65
70	70	2000	0	2000	70
75	70	2000	0	2000	75
80	70	2000	0	2000	80
85	70	2000	0	2000	85
90	70	2000	0	2000	90
95	70	2000	0	2000	95
100	70	2000	0	2000	100

Free Cooling				Mechanical Cooling			Heating		
DT	Btuh	Fan KW	Cost per Hour	DT	Btuh	Cost Per Hour	DT	Btuh	Cost per Hour
15	32400	0.994266667	($0.12)	0	0	$0.00	-30	-64800	($0.93)
15	32400	0.994266667	($0.12)	0	0	$0.00	-25	-54000	($0.77)
15	32400	0.994266667	($0.12)	0	0	$0.00	-20	-43200	($0.62)
15	32400	0.994266667	($0.12)	0	0	$0.00	-15	-32400	($0.46)
15	32400	0.994266667	($0.12)	0	0	$0.00	-10	-21600	($0.31)
15	32400	0.994266667	($0.12)	0	0	$0.00	-5	-10800	($0.15)
15	32400	0.994266667	($0.12)	0	0	$0.00	0	0	$0.00
10	21600	0.994266667	($0.12)	-5	-10800	($0.11)	0	0	$0.00
5	10800	0.994266667	($0.12)	-10	-21600	($0.22)	0	0	$0.00
0	0	0.994266667	($0.12)	-15	-32400	($0.32)	0	0	$0.00
0	0	0.994266667	($0.12)	-20	-43200	($0.43)	0	0	$0.00
0	0	0.994266667	($0.12)	-25	-54000	($0.54)	0	0	$0.00
0	0	0.994266667	($0.12)	-30	-64800	($0.65)	0	0	$0.00
0	0	0.994266667	($0.12)	-35	-75600	($0.76)	0	0	$0.00
0	0	0.994266667	($0.12)	-40	-86400	($0.86)	0	0	$0.00
0	0	0.994266667	($0.12)	-45	-97200	($0.97)	0	0	$0.00

NET BTUH	NET Costs per Hour	Bin Hours 6am-10pm	Annual BTU's	Annual Costs
-32400	($1.05)	6	-194,400	-$6.27
-21600	($0.89)	34	-734,400	-$30.29
-10800	($0.74)	157	-1,695,600	-$115.62
0	($0.58)	342	0	-$199.10
10800	($0.43)	636	6,868,800	-$272.13
21600	($0.27)	675	14,580,000	-$184.68
32400	($0.12)	789	25,563,600	-$94.14
10800	($0.23)	786	8,488,800	-$178.67
-10800	($0.34)	548	-5,918,400	-$183.75
-32400	($0.44)	402	-13,024,800	-$178.21
-43200	($0.55)	455	-19,656,000	-$250.85
-54000	($0.66)	444	-23,976,000	-$292.73
-64800	($0.77)	269	-17,431,200	-$206.41
-75600	($0.88)	195	-14,742,000	-$170.69
-86400	($0.98)	75	-6,480,000	-$73.75
-97200	($1.09)	27	-2,624,400	-$29.47
		5834	-50,781,600	-$2,460.48
		Annual Hours, TV	Total BTU's Used	Annual Energy Cost

8.1.3 TEST SCENARIO DATA FOR SAN FRANCISCO

San Francisco

% Transfer Air	80.00%	
Electric Rates	$0.12	per Kwh
Gas Rates	$1	per Therm
Fan KW/CFM	0.000497	KW/CFM
Cooling Efficiency	1	Kw/ton
Heating Efficiency	0.7	thermal efficiency
RAT	70	F
Exhaust Air	10000	cfm

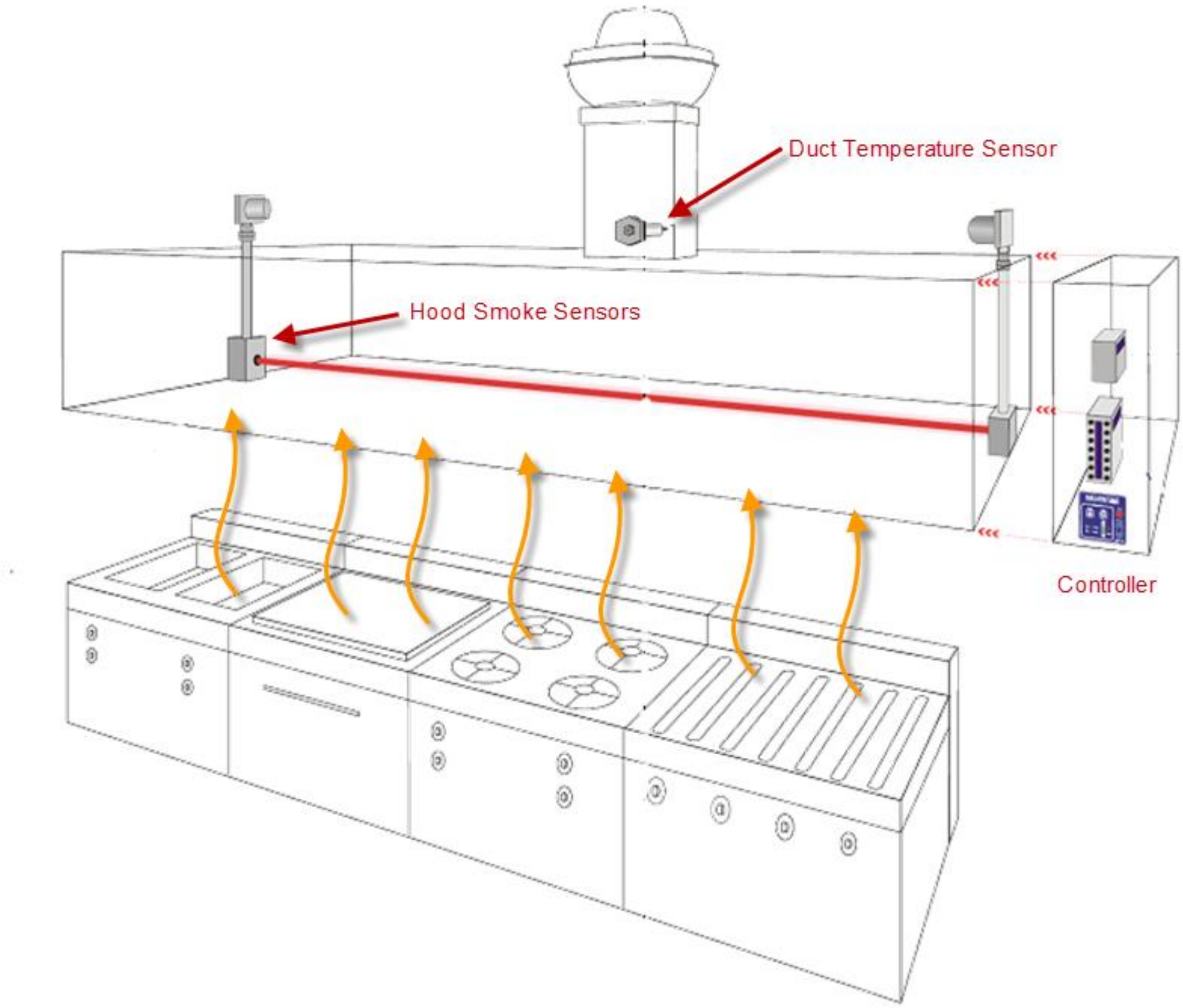
OAT	RAT	OA CFM	RA CFM	MAT CFM	MAT
25	70	2000	0	2000	25
30	70	2000	0	2000	30
35	70	2000	0	2000	35
40	70	2000	0	2000	40
45	70	2000	0	2000	45
50	70	2000	0	2000	50
55	70	2000	0	2000	55
60	70	2000	0	2000	60
65	70	2000	0	2000	65
70	70	2000	0	2000	70
75	70	2000	0	2000	75
80	70	2000	0	2000	80
85	70	2000	0	2000	85
90	70	2000	0	2000	90
95	70	2000	0	2000	95
100	70	2000	0	2000	100

Free Cooling				Mechanical Cooling			Heating		
DT	Btuh	Fan KW	Cost per Hour	DT	Btuh	Cost Per Hour	DT	Btuh	Cost per Hour
15	32400	0.9943	($0.12)	0	0	$0.00	-30	-64800	($0.93)
15	32400	0.9943	($0.12)	0	0	$0.00	-25	-54000	($0.77)
15	32400	0.9943	($0.12)	0	0	$0.00	-20	-43200	($0.62)
15	32400	0.9943	($0.12)	0	0	$0.00	-15	-32400	($0.46)
15	32400	0.9943	($0.12)	0	0	$0.00	-10	-21600	($0.31)
15	32400	0.9943	($0.12)	0	0	$0.00	-5	-10800	($0.15)
15	32400	0.9943	($0.12)	0	0	$0.00	0	0	$0.00
10	21600	0.9943	($0.12)	-5	-10800	($0.11)	0	0	$0.00
5	10800	0.9943	($0.12)	-10	-21600	($0.22)	0	0	$0.00
0	0	0.9943	($0.12)	-15	-32400	($0.32)	0	0	$0.00
0	0	0.9943	($0.12)	-20	-43200	($0.43)	0	0	$0.00
0	0	0.9943	($0.12)	-25	-54000	($0.54)	0	0	$0.00
0	0	0.9943	($0.12)	-30	-64800	($0.65)	0	0	$0.00
0	0	0.9943	($0.12)	-35	-75600	($0.76)	0	0	$0.00
0	0	0.9943	($0.12)	-40	-86400	($0.86)	0	0	$0.00
0	0	0.9943	($0.12)	-45	-97200	($0.97)	0	0	$0.00

NET	NET		Bin Hours	Annual	Annual
BTUH	Costs per Hour		6am-10pm	BTU's	Costs
-32400	($1.05)		0	0	$0.00
-21600	($0.89)		9	-194,400	-$8.02
-10800	($0.74)		98	-1,058,400	-$72.17
0	($0.58)		164	0	-$95.48
10800	($0.43)		470	5,076,000	-$201.11
21600	($0.27)		647	13,975,200	-$177.02
32400	($0.12)		1209	39,171,600	-$144.25
10800	($0.23)		1394	15,055,200	-$316.87
-10800	($0.34)		798	-8,618,400	-$267.58
-32400	($0.44)		464	-15,033,600	-$205.70
-43200	($0.55)		351	-15,163,200	-$193.51
-54000	($0.66)		188	-10,152,000	-$123.95
-64800	($0.77)		37	-2,397,600	-$28.39
-75600	($0.88)		10	-756,000	-$8.75
-86400	($0.98)		1	-86,400	-$0.98
-97200	($1.09)		0	0	$0.00
			5840	19,818,000	-$1,843.77
			Annual Hours, TM	Total BTU's Used	Annual Energy Cost

8.2 Appendix B: Measure 4: Commercial Kitchen System Efficiency Options

8.2.1 Diagram of a Demand Control Ventilation Hood



8.2.2 Sample Acceptance Test Form

This sample form is not current with ACM language above. Form shall be finalized after the comment period

2011 ACCEPTANCE REQUIREMENTS FOR CODE COMPLIANCE

Type I Kitchen Hood Acceptance Document	MECH-16-A
NA.7.5.15	Form __ of __

PROJECT NAME		DATE
PROJECT ADDRESS		
TESTING AUTHORITY	TELEPHONE	
VFD NAME / DESIGNATION		Checked by/Date Enforcement Agency Use

Intent:	Satisfy Type I Kitchen Exhaust Rates and Capture and Containment requirements per Section XXX.

Construction Inspection

1 Instrumentation to perform test includes, but not limited to:

a. Duct airflow test and balance equipment

2 Test preparation

- ☐ All exhaust, makeup, and transfer air systems installed and operational.
- ☐ All demand control ventilation systems commissioned and ready for final setpoint adjustments.
- ☐ All cooking equipment being served by Type I hoods installed and operational.
- ☐ Cooking products available to create a full load cooking test scenario.

2011 ACCEPTANCE REQUIREMENTS FOR CODE COMPLIANCE

Type I Kitchen Hood Acceptance Document	MECH-16-A
NA.7.5.15	Form __ of __

PROJECT NAME	DATE

Company: ______________________________

Signature: ______________________________ Date: ______________

License: ______________________________ Expires: ______________

A.	**Equipment Testing - Design/Maximum Exhaust Conditions (Non-DCV Systems)**		**Results**
Step 1: Set all kitchen hoods, makeup air and transfer systems to Design Airflows			
a.	Sum of all Type I Kitchen Hood Exhausts	CFM =	
b.	Sum of all other Kitchen Exhausts	CFM =	
c.	Sum of all Makeup Air Systems	CFM =	
d.	Sum of all Transfer Air Systems	CFM =	
Step 2: Operate all heat producing cooking equipment at full operational conditions. Apply sample cooking products when appropriate. Observe any escaping plume of heat and/or cooking smoke beyond the edges of the Type I Hoods.			
e.	Type I Exhaust Fan Tag		
f.	Adjust grease exhaust hood CFM until the plume extends no more than 3" from hood edge		-
g.	Final Design Maximum Exhaust CFM	CFM =	
i.	If hoods are UL Listed and recorded CFM is greater than the UL listed, reduce CFM to listing by using hood side panels, back plates, or relocating supply outlets to improve the capture and containment performance at lower exhaust CFMs.	Complies with Listing (Y/N)	
ii.	Retest using improvements, Describe measures, and Record Final Design Maximum Exhaust CFM	CFM =	
h.	Adjust Makeup Air air volumes up or down to match Exhaust adjustment		-
i.	Final Design Maximum Makeup Air CFM	CFM =	
Step 3: Repeat test for each Type I Hood			

B.	**Equipment Testing - Design/Maximum Exhaust Conditions (DCV Systems)**		**Results**
Step 1: Set all kitchen hoods, makeup air and transfer systems to Design Minimum Airflows			
j.	Sum of all Type I Kitchen Hood Exhausts	CFM =	
k.	Sum of all other Kitchen Exhausts	CFM =	
l.	Sum of all Makeup Air Systems	CFM =	
m.	Sum of all Transfer Air Systems	CFM =	
Step 2: Operate an even distribution of cooking equipment under hood at 50% full operating power with no cooking products to witness fan systems engage from Off to Minimum Flow setpoint based on hood temperatures alone.			
n.	Operating Speed at Minimum Setpoint	% of Full Speed	
Step 3: Operate all heat producing cooking equipment at full operational conditions. Apply sample cooking products when appropriate. Observe any escaping plume of heat and/or cooking smoke beyond the edges of the Type I Hoods.			
o.	Type I Exhaust Fan Tag		
p.	Exhaust and Makeup Air System Ramp Up in reaction to heat and smoke	Y/N =	
q.	Adjust grease exhaust hood Max CFM until the plume extends no more than 3" from hood edge		-
r.	Final Design Maximum Exhaust CFM	CFM =	
s.	Adjust Makeup Air air volumes up or down to match Exhaust adjustment		-
t.	Final Design Maximum Makeup Air CFM	CFM =	
i.	If hoods are UL Listed and recorded CFM is greater than the UL listed, reduce CFM to listing by using hood side panels, back plates, or relocating supply outlets to improve the capture and containment performance at lower exhaust CFMs.	Complies with Listing (Y/N)	
ii.	Retest using improvements, Describe measures, and Record Final Design Maximum Exhaust CFM	CFM =	
Step 4: Repeat test for each Type I Hood			

☐	PASS: All **Design Declaration**, **Pre-Test Inspection** responses are complete and **Testing Results** responses are positive (Y - yes)
☐	FAIL: Any **Pre-Test Inspection** responses are incomplete *OR* there is one or more negative (N - no) responses in **Testing Results** section. Provide explanation below. Use and attach additional pages if necessary.